Optimum design of perforated plug mufflers using a neural network and a genetic algorithm

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Abstract: Research on new techniques of perforated plug silencers has been well addressed. Most researchers have explored noise reduction effects based on a pure plane wave theory. However, the maximum noise reduction of a silencer under a space constraint, which frequently occurs in engineering problems, is rarely addressed. Therefore, the optimum design of mufflers becomes an essential issue. In this paper, to save the design time during the flexible optimum process, a simplified mathematical model of a muffler is constructed with a neural network with a series of real data – input design data (muffle dimensions) and output data (theoretical sound transmission loss (STL)) were approximated by a theoretical mathematical model (TMM) in advance. To assess the optimal mufflers, the neural network model (NNM) is used as an objective function in conjunction with a genetic algorithm (GA). Moreover, the numerical cases of sound elimination with respect to various parameter sets and pure tones (500, 1000, and 2000 Hz) are exemplified and discussed.

Before the GA operation is carried out, the approximation between TMM and real data is checked. In addition, both the TMM and NNM are compared. It is found that the TMM and the experimental data are in agreement. Moreover, the TMM and NNM conform.

Optimal results reveal that the maximum amount of the STL can be optimally obtained at the desired frequencies. Consequently, the optimum algorithm proposed in this study can provide an efficient method to develop optimal silencers in industry.

Keywords: generalized decoupling technique, perforated plug muffler, four-pole transfer matrix, neural network model, optimization, genetic algorithm

1 INTRODUCTION

Muffler research used in engine noise was started by Davis et al. in 1954 [1]. On the basis of the plane wave theory, the analysis of mufflers using four-pole parameters is well developed by Igarashi and Miwa [2–4]. Considering both flowing rate and temperature gradient, the studies of simple expansion mufflers without perforated holes have been well addressed [5–7]. To increase the acoustical performance of a muffler, the assessment of a new acoustical element – internal perforated plug tubes – was discussed by Sullivan and Crocker [8]. On the basis of the coupled differential equations, a series of theoretical and numerical techniques have been proposed in decoupling the acoustical problems [9–12]. In 1981, Jayaraman and Yam [13] developed a method to find an analytical solution; however, a presumption of the velocity equality within the inner and outer ducts, which is not reasonable in the real world, is required. To overcome this drawback, Munjal et al. [14] provided a generalized decoupling method. Regarding the flowing effect, Peat [15] publicized the numerical decoupling method by finding the eigenvalue in transfer matrices.

As the constrained problem is mostly concerned with the necessity of operation and maintenance in practical engineering work, there is a growing need to optimize the acoustical performance under limited space. However, the need to investigate the optimal muffler design under space constraints is